

A COMPARISON BETWEEN WIND VELOCITIES AS RECORDED BY THE DINES AND ROBINSON ANEMOMETERS

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The Robinson cup anemometer is the standard wind-velocity instrument of the Weather Bureau. This anemometer, while of considerable value in recording average wind movement, is less satisfactory for recording gusts. A casual examination of a record from a Dines' pressure tube anemometer reveals the fact that the air movement is rarely, if ever, stable, but is characterized by alternating gusts and lulls.

Any cup-type anemometer has an inherent fault in recording wind. The cups, spindle, gear train, and recording mechanism all have a certain inertia, regardless of friction, that make an appreciable change in force necessary to accelerate or decelerate the instrument. This force may be small, but can never be entirely removed, no matter how light the mechanism may be.

The Dines recorder also has a certain inertia, but this is partially overcome in the construction of the instrument and by the balancing of the recording float in the liquid medium.

Both instruments are defective in that they cease to record wind movement at very low velocities. The Robinson anemometer has a stopping point between 1 and 2 miles per hour, while the Dines lower limit ranges around 1 mile per hour. It is a significant fact, however, that wind velocities in wind tunnels, where exact determinations are desired, are all measured with a pitot tube, similar in principle to a Dines anemometer.

The Weather Bureau has given more attention to the Robinson anemometer than to any other type of wind recorder as it is well adapted to the type of register in use. It is also comparatively easy to reduce the record made by it to a tabular form. However, there remains one major question: Does the Robinson anemometer or any cup-type anemometer, accurately record the structure of the wind?

Fleming (1) refers to the extensive use of the Dines pressure-tube anemometer in England and states that it is especially adapted to recording pressure during gusts and rapid velocity changes. Sherlock and Stout (2) conclude that "Undoubtedly, the instrument gives an accurate record only when the recorded velocity is averaged over a sufficiently long period of time to include one or more complete cycles of fluctuation." This conclusion was based on a cup-type anemometer recording $\frac{1}{10}$ mile of wind and for an extremely rapid rate of paper travel. Pinkerton (3) also concludes that "The cup anemometer, because of its large inertia, is too sluggish for velocity measurements of wind gusts having accelerations greater than 2 m. p. h. per second." This author again uses an extremely rapid paper travel.

Marvin (4) has investigated numerous factors bearing on the behavior of the Robinson cup anemometer but treating more extensively of its mechanical details. It has been assumed by some investigators that cup anemometers will record gusts accurately if sufficiently rapid paper travel is used in recording the data from a $\frac{1}{10}$ mile instrument. This assumption may be correct, but it is obviously impracticable to provide the necessarily rapid paper travel in ordinary practice. Therefore, these comparisons were made on the basis of the normal operations of the instruments.

The importance of gust velocities to engineers cannot be exaggerated. Accordingly, the records from a Dines pressure-tube anemometer and a Robinson cup anemometer, for Washington, D. C., were examined.

The records cover the calendar year 1936 and are from instruments exposed at the same elevation and under similar conditions of exposure. The general surroundings that may affect the recording of these instruments are satisfactory to the northwest, but are highly detrimental to the south and southwest where a 6-story hospital building 200 feet distant interposes an effective barrier.

This building presents the same type of obstruction experienced by the British Meteorological Office at Lizard (5). There it was found that a building 30 feet high and 90 feet from an anemograph 40 feet high, necessitated raising the head of the instrument to 75 feet in order to obtain an unobstructed flow of air. As the conditions are quite similar, a comparison was made with the conditions at the Weather Bureau, and it was found that the height of the anemograph head would need to be approximately 178 feet.

The only valid comparison possible between a Dines and Robinson anemometer would be in a wind tunnel under varying velocities, both accelerating and decelerating, as well as under simulated gust conditions. This would necessarily involve a complicated arrangement of apparatus and might not be practicable at the present time. Herein lies an inherent weakness in calibrating anemometers from determinations in wind tunnel exposures. Gusts play an important part in the operation of an instrument as exposed in actual practice which is not reflected in the more uniform flow in a wind tunnel. This is apparent in a glance at a Dines record sheet.

An approximate relationship between the two instruments was obtained by examining the Dines record and selecting certain periods when the wind appeared to be structurally constant. It is recognized that such selections for varying time periods are open to many objections. As a check on the general study, a period was taken when individual gusts were selected without special reference to surrounding velocities. As a further, incidental check, gusts were selected where they were markedly greater than any surrounding velocities and were considered as isolated. Several of these occurred in the warm season under thunderstorm conditions and represented practically an instantaneous increase in velocity from nearly zero to 30 or 40 miles per hour.

After securing the selected gusts, noting dates and times of occurrence, the corresponding velocities of the Robinson anemometer were obtained. In determining the fastest single mile on the Robinson record, certain variations in the time of occurrence were necessary due to lack of absolute synchronization of the two recorders. In selecting the fastest single mile, the time occasionally varied some few minutes from the time of the gust.

Another comparison between the two was attempted by averaging the records. For the periods covered in the Dines record, the average velocity was obtained by estimation. The Robinson average for the same period was obtained by measuring the individual miles and obtaining the mean. This resulted in an estimated velocity

of the Dines somewhat lower than for the Robinson. At first glance this appears to indicate a fixed bias toward lower average velocities on the Dines. However, some other factors may enter into the matter. It is possible that the inertia of the cup anemometer may tend to higher velocities through the impetus received from the gusts and continue through the lull between them. This is only a suggestion, however, and may be disproved by later detailed investigations.

It is also recognized that the relatively low rate of paper travel used by the recorders of both instruments effectively precludes any direct, close comparison. In Dines' original experiment (6), the rapid rate of paper travel enabled him to planimeter the areas beneath the curves and thus obtain an accurate estimate of the average wind velocity. In this comparison he found the pressure-tube anemometer recorded some 14 percent higher than the cup-type anemometer. The difference found in this

fastest single mile is recorded in Weather Bureau publications as the "extreme" velocity. Thus, for a corrected "extreme" of 50 miles per hour the average gusts as recorded on a Dines instrument would be 59 miles per hour, with an extreme gust of 73 miles per hour.

The coefficient "b" obtained with the check data was exactly the same as that shown in figure 2. Coefficients were also obtained for eight directions as follows:

N	NE	E	SE	S	SW	W	NW
1.72	1.07	2.30	.79	1.42	.85	1.09	1.34

As previously stated, the exposure to the northwest represents the best conditions. The rapid and violent fluctuations shown from east through southwest clearly indicate a highly turbulent air structure from these directions,

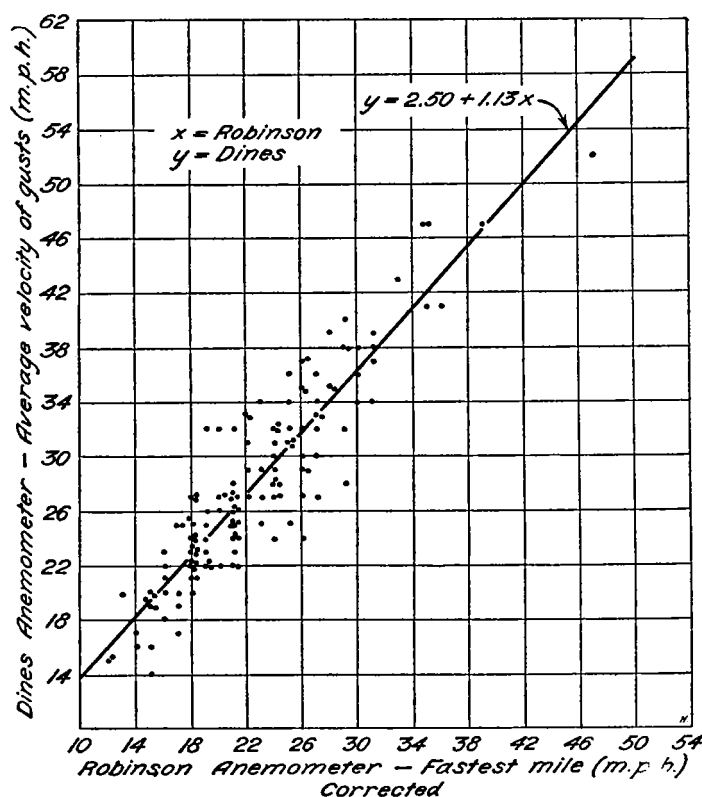


FIGURE 1.—Relation between average gust velocities as recorded on the Dines anemometer and the fastest single mile recorded by the Robinson anemometer.

study was, roughly, 22 percent in the opposite direction, clearly indicating that the estimates of velocity for the Dines were too low.

Figure 1 shows the relationship between the average velocities of the gusts for the periods and the corrected velocities of the fastest single mile of the Robinson instrument.

Figure 2 shows the relationship between the extreme gust recorded on the Dines anemometer and the corresponding corrected fastest single mile on the Robinson anemometer.

The coefficient "b" of the regression equations represents the "factor" to be applied to the Robinson record to reduce it to the Dines, either as average gusts, or extreme gust. Thus, in figure 1, the factor is 1.13 and in figure 2 it is 1.42. To reduce the Robinson record to a Dines record the following procedure can be used: The

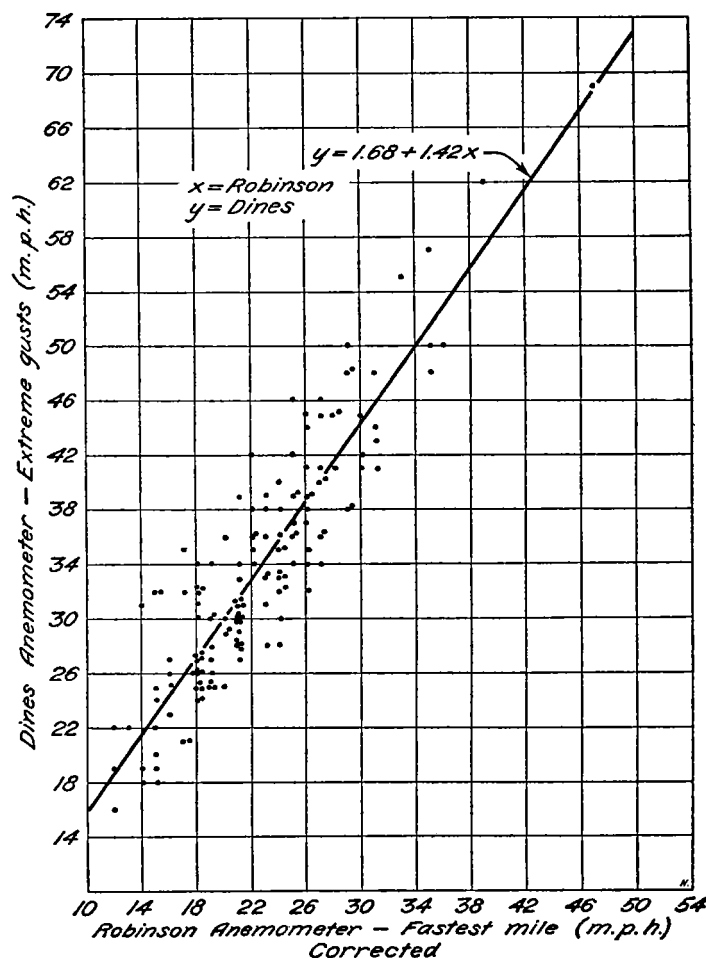


FIGURE 2.—Relation between the extreme gust velocity as recorded on the Dines anemometer and the fastest single mile recorded by the Robinson anemometer.

although the exposure itself does not indicate excessive interference, except for the large building previously noted.

Other variations in the comparisons show that varying conditions affect the factors but little. For example, based on gusts where the velocities show progressive increases, the factor is 1.36. An attempt to show the inertia of the cup anemometer brought out the following: The increase in velocity was noted on the Dines instrument and the percentage change in velocity for both the Dines and Robinson was recorded. When low starting-velocities were chosen between 3 and 15 miles per hour, the increase in the Dines record ranged from 100 to over 400 percent, with corresponding changes in the Robinson record from 91 to 112 percent.

Higher starting velocities, however, show conclusively that the Robinson responds more readily than at the lower ranges. For example, from 30 to 40 miles per hour, the Dines increased from 52 to 20 percent, but the Robinson from 89 to 33 percent.

In the case of the isolated gusts, previously discussed, due to the conditions mentioned in the above paragraph, the factor is 1.06. As the gust reaches its maximum and minimum in an extremely brief interval, the impulse given the cup anemometer must carry it through the corresponding minimum and cause it to register higher than it would normally.

The factor for average Dines velocities as compared to Robinson velocities was only 0.78, but was discarded for the reasons previously mentioned.

Check comparisons were attempted with records from New York City and Chicago, but proved to be of no value for the purpose.

No attempt will be made to draw conclusions from the data as it is realized that these are only approximations.

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TROPICAL DISTURBANCES OF AUGUST 1938¹

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[Marine Division, Weather Bureau, Washington, September 1933]

August 8-10.—The first clearly defined tropical disturbance of the 1938 season appeared on the morning of August 8 among the islands to the eastward of Puerto Rico. Early in the day, the Am. S. S. *West Isleta* experienced heavy squalls of hurricane intensity and rough, heavy sea and swell from the east-southeast. The ship was then near 21° N., 64° W.

During the 8th the center of the disturbance passed some distance to the northward of Tortola and caused some damage on the island of Anegada. The lowest barometer reading reported from Tortola was 29.58 inches at 1:44 p. m. (local time) of the 8th.

On the 9th and 10th squally conditions progressed rapidly west-northwestward, along the northern coasts of Haiti and Cuba, and into the Florida Straits. Its progressive movement probably exceeded 20 miles an hour. However, no definite cyclonic circulation was charted after the 8th. There are no reports to indicate that the disturbance was of more than moderate intensity at the time of its maximum development. Advisory messages were issued from San Juan on the 8th and from Jacksonville on the 9th and 10th.

August 9 to 14.—While the preceding squally condition was in progress on the 9th and 10th, a slight disturbance passed rapidly through the Windward Islands into the eastern Caribbean Sea. Advisory information was issued on those dates from the Weather Bureau forecast center at San Juan. It is not possible with reports at hand to trace the center of the disturbance with any assurance of accuracy beyond 14° N., 67° W., which was its approximate position at 7 p. m. (eastern standard time) of the 10th. However, its rapid progressive movement westward and the subsequent appearance of a rapidly moving tropical cyclone in the western Caribbean Sea on the 12th, indicates the probability that it continued to move west-northwestward on the 11th and is identical with the latter.

On the morning of August 12 a disturbance of marked intensity was centered near Grand Cayman Island, where shortly before 7 a. m. (eastern standard time) the wind reached a maximum velocity of 95 miles an hour from the east. Maintaining marked intensity, but with rather small diameter, the storm passed through the Yucatan Channel on the night of August 12-13, moved rapidly northwestward to the Central Gulf and thence north-northwestward into western Louisiana. Its average rate

of progressive movement across the Gulf was 18 to 20 miles an hour. The storm passed inland over Cameron and Calcasieu Parishes, during the evening of the 14th with the center a short distance west of Lake Charles at about 8:30 p. m. (eastern standard time).

The report of the forecaster at New Orleans, R. A. Dyke, includes the following:

Though the storm was without a deep center of low pressure, as far as known, and winds were rather weak on the left side, the winds to the right of the center showed considerable strength over the Gulf, a wind of force 11, or "storm," being reported by the steamship *John D. Archbold* at 9 a. m., eastern standard time, of the 14th, in latitude 27.1° N., and longitude 91.9° W.; and winds were estimated as of hurricane force at Grand Chenier near the coast of eastern Cameron Parish, La., about 7 p. m., of the 14th. At Lake Charles, La., 35 miles inland, with the disturbance decreasing in intensity, a southeast wind of 50 miles per hour was recorded between 8:00 and 8:30 p. m., with gusts up to 60 miles per hour; and the lowest pressure was 29.56 inches at 8:30 p. m. At Port Arthur, Texas, the lowest pressure was 29.73 inches at 8:20 p. m. and maximum wind velocities of 32 to 34 miles per hour from the east and southeast were recorded between 2:30 p. m. and 4:12 p. m.

The gales attending the storm drove in many sea birds, which were observed at the game preserve of Avery Island, Iberia Parish.

The movement of the storm favored increasing tides on the east coast of Texas on the 13th-14th and on the Louisiana coast on the 14th. The highest tides at various points follow: Galveston, 3.6 feet above mean low tide, at 6 to 7 p. m., on the 14th, or 2.8 feet above normal predicted tide; Sabine Pass, 7 p. m., 4.1, or 2.7 feet above normal predicted tide. Water was 4 to 5 feet above mean low tide on the coast of Cameron and Vermillion Parishes with lowlands flooded for depths of 1 to 4 feet. The storm caused a rise of about 2.5 feet in the Atchafalaya River at Morgan City, La., and tide slightly more than a foot above normal predicted tide at Grand Isle, La.

Torrential rainfall preceding and attending the passage of the storm caused extensive overflow of crops and detours or interruption of highway traffic for a considerable distance inland, between twenty and forty miles east of the path of the storm center, especially in Jefferson Davis Parish and neighboring localities.

Damage to buildings, wires, derricks, piers, and other property is estimated at \$133,000; to crops, \$110,000, principally to rice, but including considerable cotton damage from the heavy rains, and slight damage to sugarcane snapped off by the wind. Total losses are conservatively estimated at \$243,000.

At 10:30 a. m. of the 15th, about 12 hours after the storm center had passed, a small tornado occurred at Kinder, Allen Parish, 28 miles northeast of Lake Charles, destroying a house and prostrating two barns, fences, and some trees, with damage of \$2,000 reported.

Advisory warnings were issued from Jacksonville on the 11th and 14th. Storm warnings were hoisted on the

¹ Tracks of the tropical disturbances of August are shown on chart X.